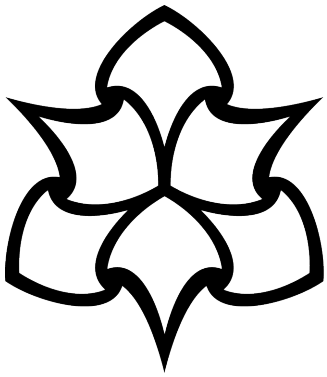

REVOLUTIONIZING THE FUTURE OF THE CONSTRUCTION INDUSTRY: STRATEGIZING AND REDEFINING CHALLENGES

SANTI EDRA NISA LAU[1], EEYDZAH AMINUDIN[1], ROZANA ZAKARIA[1], CHAI CHANG SAAR[2], NUR IZIEADIANA ABIDIN[1], AHMAD FARHAN ROSLAN[3], ZUHAIRI ABD HAMID[3], MARIA ZURA MOHD ZAIN[3], ERIC LOU[4] & AHMAD BUKHORI SHAHARUDDIN[1]
[1]Department of Structure and Materials, School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Malaysia
[2]Faculty of Engineering, Computing and Science, Swinburne University of Technology Sarawak, Malaysia
[3]Construction Research Institute of Malaysia, Malaysia
[4]Manchester Metropolitan, UK

ABSTRACT
The construction industry is ripe for disruption. With the vast pace of new technologies innovating the whole life cycle of construction, the revolution seems vital. The ideas of digitization and digitalization in Industrial Revolution 4.0 are currently entering the market in most industries including the construction industry. While most other industries have undergone tremendous changes recently, the construction industry has been reluctant about plenarily embracing the newly emerging technological adoption. Varying sophistication of construction, this paper was empirically evaluating large construction firms' point of view on challenges of the construction industry in the era of Revolution 4.0 using survey data form. The findings reveal that construction companies need to deal with the manifold PESTEL (political, economic, social, technological, environmental, and legal) challenges. By adopting the Revolution 4.0 hindered by lack of policies, financial problem, limited demand for innovation among large economic players, lack of trust towards foreign partners, and limited adaptability of foreign software. Clearly, this paper helps scholars and industry players to redefine the development of the construction industry into detailed strategic plans or policies in the future. In a nutshell, transforming the construction industry into digitization and digitalization might confront few challenges but the long-term benefits obtained throughout application should not be forgotten.
Keywords: industrial revolution, fourth industrial revolution, technology, digitization and digitalization.

1 INTRODUCTION

The industry is currently witnessing the fourth industrial revolution where enormous transformation in terms of technologies has occurred. Technology is constantly changing and bring rapid development on the industry performance. Previously, the world depends too much on the people for the first industrial revolution until it reached the maximum point where it caused immigrants problem in certain countries such as Malaysia. The ideas of digitization and digitalization are currently entering the market in most industry including construction industry and it can be a new solution to increase the quality of work and also reduce the cost and time of construction. Digital technology disruption that is caused by rapid development in digitalization has driven changes in the business process of industry [1]. In an effort to tackle this era, some countries have taken their own initiatives and strategic plan. At the same point, some industrial companies are ready to embark on this new revolution after Industry 4.0's initiation in Germany back in 2011 [2].

When referring to the construction industry, the revolution 4.0 process took place a bit slower compared to other industries. Many industries have already dived into digitalization in their daily business activities such as manufacturing, automobile, and banking industry due to the positive impact towards productivity, accuracy, efficiency, and customer

WIT Transactions on The Built Environment, Vol 192, © 2019 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/BIM190101

satisfaction [3]. Construction sector contributes 6% of global GDP and can account more than 8% of developing countries' GDP [4]. Thus, the successful adoption of new technologies can bring great impact to economic development. However, the implementation of it is not as easy as expected. It would be incredibly illogical to think that the implementation of digital technology comes without any problems. Against this background, this paper gives a little insight into the challenges of the construction industry in the era of revolution 4.0 in Malaysia. An understanding of the issue of implementing revolution 4.0 in construction industry must be clearly examined to successfully entered this new era.

This paper has been divided into a few sections. In Section 2, a related work regarding fourth industrial revolution prior to construction industry are reviewed. Then, in Section 3, the process of tackling the issue and challenges of Construction Industry in The Era of Revolution 4.0 is explained clearly. Later, the main result is presented in Section 4. Section 5 discusses the significance of overall result obtained. Finally, Section 6 presents conclusion remarks and proposed the future related work.

2 REVIEW OF INDUSTRIAL REVOLUTION 4.0 AND CONSTRUCTION 4.0

2.1 New era of industrial revolution

So far, the world has been introduced to four industrial revolutions and it can be presented as a path as depicted in Fig. 1. The first industrial revolution came about as a result of mechanisation [5] and mainly supported by water and steam power engine [6]. It helped the industry to escape from manual work to the first manufacturing processes and bring changes to the quality of life of human [7].

The second industrial revolution occurred due to mass production and driven by electrical energy [5], [6]. It caused the production process to be more complicated yet automated. As a result, information and communication can be delivered among people thanks to electricity contribution [8].

The use of electronic and automated production has resulted to third industrial revolution [9]. It created an opportunity for flexible production, where a variety of products is manufactured using programmable machines [7]. At this phase, the early integration of information technologies and computers can be seen. Now, the introduction of the Internet of Things and Services into the industry is ushering in a fourth industrial revolution.

Fourth industrial revolution will take the industry to the next level, where machines will redefine themselves in the way they communicate and perform individual functions. It characterized by the advanced digitalization and integration, use of internet and "smart" objects which, contributes to interconnected digital world today [10].

According to [11], Internet of Things (IoT) or Cloud Computing technologies are terms stand for Revolution 4.0. Definition of fourth industrial revolution can be different as

Figure 1: Industrial revolution [5].

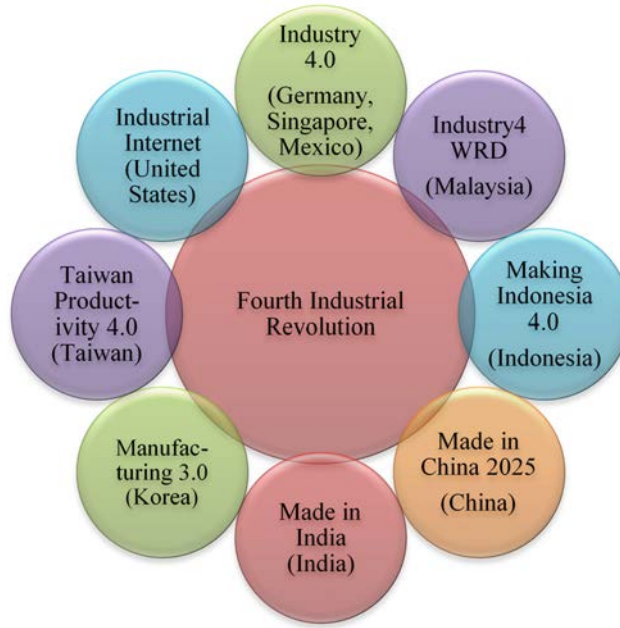

Figure 2: Subset of the fourth industrial revolution.

everyone has a different point of view. On the other hand, [8] stated that, Fourth Industrial Revolution is mainly related to technologies such as Internet of Thing (IoT) which gives birth to the Industrial Internet of Thing (IIoT), big data, augmented reality (AR), virtual reality (VR), cybersecurity, energy efficiency tools, and equipment. Digitalization, digitization, and smart factory are among other hot keywords at this phase.

The fourth industrial revolution is a wide subject. Every country has different way to define fourth industrial revolution. Each industry also defined it differently. The notion of Industry 4.0 term was first proposed by Germany as it represents the latest revolution of manufacturing industry. People often misunderstood the concept of fourth industrial revolution and Industry 4.0. To make it simple, Industry 4.0 is a subset of fourth industrial revolution. Recently, lots of initiatives from different countries and most of them coined different terms to represent fourth industrial revolution. Fig. 2 shows the term used by different countries prior to the fourth industrial revolution.

2.2 Future of construction

The spread of the digitalization has the potential to transform the whole industry. The engineering and construction industry are no exception. Construction industry defined as industry that includes only companies that are involved with building and civil engineering [12]. Productivity increment can happen in many different ways, including deploying the latest technologies, such as of the use of scrum techniques or the use of robots to replace onsite labours [13]. However, changes in construction can only be triggered by the openness of practitioners towards emerging technologies. Being open to emerging technologies is a key that will assist in overcoming the challenges faced today and in the future. Table 1 displays the related emerging technologies when discussing construction.

Table 1: Technologies in construction [14].

Technologies involved construction	Abbreviation
Internet of Things	IoT
Additive Manufacturing	AM
Modularization and Prefabrication	M&P
Automation and Robot	A&R
Human–Computer/Robot Interaction	HCI/HRI
Laser Scanning and Photogrammetry	L&P
Virtual Reality/Augmented Reality	VR/AR
Building Information Modelling	BIM
Simulation and Algorithm	S&A
Cloud Computing	CC
Big Data	BD

Fourth industrial revolution is supposed to guide all the countries to a new era of modern construction. Engagement of construction with digitalization brings new term such as Construction 4.0 [3], Construction automation [13], and Digital Construction [15] are among the term used to refer to current construction revolution.

In the economic perspective, it cannot be denied that construction brings great impact to economic development. But digitalization and digitization seem to be a concrete wall to this industry. According to [16], the construction continues to budget the least for information technology compared to other industries. It indicates that stakeholders have least interest in investing in new technologies for their company. Although, some might argue that the extent of its contribution is not important and not as powerful as the other sectors. However, it has direct and significant contribution to GDP. In a nutshell, construction is a flat industry that supports the development of other industry.

3 METHODOLOGY

This study addresses this topic based on the perspective of construction sector professionals. In this paper, the questionnaire survey was utilized in order to identify the challenges faced by construction firms with regards to fourth industrial revolution implementation. It was built in a form of closed-ended questions for which the questions are set out for the respondents to tick (√) the possible answer which best described according to their opinion. According to Fowler (2011), a survey with closed-ended questions is convenient to obtain feedback from a large number of people and ease the researcher with the process to analyse the statistic. As compared to the open-ended question which offers the respondents to provide their own answer without having a limitation in giving their information, in closed-ended question is comprehensive and exclusive as the respondents are only required to find one best answer based on the choices given in the range from “strongly agree” to “strongly disagree”.

This study consists of two (2) main sections only: Section A and B. Section A describes the questionnaire respondent demographic profile, which made it possible to define the company size, working experience, and also its role in the company; Section B consists of the challenges in implementing of digitalization and digitization in the construction industry. Multiple-choice questions were used to investigate the problems and how genuine were the

Table 2: Crosstabulation management level and working experience.

What is your management level in your company?		What is your working experience?						Total
		< 5	5–10	11–15	16–20	21–25	> 25	
Junior Executive	% of Total	9.4%	0.0%	0.0%	0.0%	0.0%	0.0%	9.4%
Middle Executive	% of Total	0.0%	6.3%	9.4%	9.4%	0.0%	0.0%	25.0%
Senior Executive	% of Total	0.0%	0.0%	0.0%	28.1%	12.5%	25.0%	65.6%
% of Total		9.4%	6.3%	9.4%	**37.5%**	12.5%	25.0%	100.0%

Table 3: Crosstabulation management level and number of employees.

What is your management level in your company?		What is the number of employees in your organisation?				Total
		< 5	5–19	20–50	> 50	
Junior Executive	% of Total	0.0%	3.2%	3.2%	3.2%	9.7%
Middle Executive	% of Total	3.2%	0.0%	6.5%	16.1%	25.8%
Senior Executive	% of Total	6.5%	12.9%	16.1%	29.0%	64.5%
% of Total		9.7%	16.1%	25.8%	**48.4%**	100.0%

problems experienced at the companies based on Likert scale. The survey was distributed by an online link.

Based on the data obtained, an analysis was conducted by using SPSS to analyse the demographic information with Frequency Analysis and using SPSS in conducting Reliability Analysis and Factor Analysis for Likert scale questions. By using an online platform, we received 32 answers that we could analyse. Most responding respondents are from professional and from large firms (Tables 2 and 3), with the proportion of 16–20 working experience years (37.5%) and more than 50 workers in each organisation (48.4%).

4 ADDRESSING CHALLENGES OF CONSTRUCTION TOWARDS IR4.0

This section presents and discusses the results of the issue and challenges occurred during the implementation of revolution 4.0 in the current construction industries. The following questions were raised in Section B in order to identify the main challenges of industrial revolution to construction. The practicability of challenges was analysed based on scale of 1 to 5.

The questions were numbered on the questionnaire from Q9 to Q14:

- The challenges of the industrial revolution to construction “Politic” (Q9).
- The challenges of the industrial revolution to construction “Economic” (Q10).
- The challenges of the industrial revolution to construction “Social” (Q11).
- The challenges of the industrial revolution to construction “Technological” (Q12).
- The challenges of the industrial revolution to construction “Environment” (Q13).
- The challenges of the industrial revolution to construction “Legislation” (Q14).

Tables 4–9 summarise these challenges by grouping them in six categories using the PESTEL framework. The categories are: political (P), economic (E), social (S), technological (T), environmental (E), and legal (L). In doing so, the challenges in each category can be investigated clearly.

From a managerial point of view, lack of policies designed and fragmented business structures and practices [3] are the top two main challenges faced by the firm in promoting the fourth industrial revolution. Due to the specific characteristics of the construction industry as well as the complex nature of the construction projects, re-engineering of business practices required a deep study.

From an economic view, construction companies are hesitating to invest due to high cost of implementation [5], [17] including technical equipment investments also training and education fee as well as infrastructure maintenance [18]. Return of investment cannot be seen clearly at the early stage. Thus, incentives reduction and funding program can be seen as a stepping stone for them to start investing. Later, when the benefits outweigh the cost of implementation, it can bring a greater contribution to the quality and time of project completion.

Table 4: Political issues.

No	Challenges	Factor analysis
1.	Lack of public policies designed to promote industry 4.0	0.886
2.	Requires the re-evaluation and re-engineering of business practices	0.871
3.	Lack of a clear digital operations vision	0.848
4.	Lack of support/leadership from top management	0.813
5.	Lack of understanding of the strategic importance of Industry 4.0	0.804
6.	Reluctance to initiate a new workflow	0.801
7.	Inefficient regulatory framework	0.800
8.	Construction companies are hesitating to adopt due to the unclear benefits	0.714
9.	Lack of a national long-term strategy to develop the industry 4.0	0.766
10.	The decentralized organization of the construction companies, as well as the temporary nature of the construction projects, is a barrier to innovation	0.707

Table 5: Economic issues.

No	Challenges	Factor analysis
1.	High cost for implementation (technical equipment, training and education and external consultancy fees)	0.914
2.	Limited capabilities for investments in new technologies	0.894
3.	High financial investment requirements (maintenance)	0.866
4.	Not offer enough to gain financial benefits	0.865
5.	Benefits do not outweigh the cost	0.837
6.	The concern of return on investment	0.818
7.	Unclear economic benefit of digital investments	0.791

Table 6: Social issues.

No	Challenges	Factor analysis
1.	Low awareness of Industry 4.0 and its applications among companies	0.892
2.	Low rate of collaboration between the academy and industry	0.888
3.	The use of new technologies requires enhanced skills	0.844
4.	Process-dependent systems that make greater use of technology may prove to be a major challenge for existing employees	0.822
5.	Major concerns of employees about the adoption of new technologies are the job-loss, as they might be replaced by machines, computers or robotics	0.812
6.	The absence of digital culture and the right training	0.799
7.	Require retraining or further training in operating these new applications if they want to make full use of them	0.741
8.	Lack of understanding the interplay between technology and human	0.706
9.	Misalignment between academy and industry	0.672
10.	Absence of educational programs specialized in digitalization and automation	0.668
11.	The pressure to improve services while raising quality and lowering costs	0.619
12.	Lack of employee readiness	0.615
13.	Lack of knowledge about Industry 4.0	0.594
14.	The in-house technical staff are not ready to be trained	0.536

Table 7: Technological issues.

No	Challenges	Factor analysis
1.	Unreliable broadband connectivity or the lack of access to high-bandwidth connectivity for collaboration applications	0.883
2.	Technology changes over time and has to be updated constantly	0.817
3.	Do not have the technology	0.773
4.	Need a full implementation and will take a lot of time	0.747
5.	Higher requirements for computing equipment	0.661
6.	The problem in managing these large quantities of data	0.570
7.	Requires new modelling techniques and data formats	0.541

Table 8: Environment issues.

No	Challenges	Factor analysis
1.	Production of metal (lithium, dysprosium, rhenium) will be increased due to technological change	0.807
2.	The unknown potential impact on sustainability and the environment	0.750
3.	The infrastructure to maintain and provide secure data transfer will concentrate a large number of resources and energy	0.740
4.	Negative effect on energy use, global warming, and climate change	0.707
5.	Disregard responsible consumption, motivated by the availability of the on-demand customized product	0.684

Table 9: Legislation issues.

No	Challenges	Factor analysis
1.	Concerns around the loss of control over your company's intellectual property	0.890
2.	Lack of consistent BIM standards (software incompatibility)	0.864
3.	Data theft, industrial espionage and attacks by hackers	0.812
4.	Lack of codified and shared project knowledge	0.802
5.	Unresolved questions around data security and data privacy in connection with the use of external data	0.800
6.	Lack of digital standards, norms and certification	0.754
7.	Cyber-attacks and viruses can have a devastating impact	0.747
8.	Weak support to inventions and patent registration	0.732
9.	Lack of standards and reference architectures	0.673
10.	Industry 4.0 will need to comply with the law, existing legislation will also need to adapt to take new innovations into account	0.662
11.	Lack of multi-protocol tags and readers	0.644

From a socio-cultural and ethical point of view, it can be concluded that new technologies adoption required a new skill and it may bring harm to the existing workers. Investing in new technologies required the workers that can handle it skilfully. The choices that construction company have are either sending the existing worker for retraining or change the unskilled worker to a skilled worker. Re-skilling or up-skilling their existing workforce to suit their requirements can be seen as preparation to enter the Revolution 4.0 market.

From technological perspective, technology revolving rapidly and regular maintenance have to be updated constantly. The investment of technology needs a proper study and will take a lot of time. Other than that, technology must be supported with high-bandwidth connectivity for collaboration applications to avoid the connection loss. The fourth industrial revolution is mentioning about connectivity as part of the main element. Unreliable

broadband connectivity will bring problem in managing large quantities of construction data during data sharing process.

From the survey, it becomes clear that fourth industrial revolution exerts its impact on environmental too. Behind this result, few papers strongly support the claim. Technology is made up of few metals such as lithium, dysprosium, rhenium and of these are difficult to extract, handle, purify, and recycle [15]. Recycling process will become an issue when the technology no longer be used in the future. Thus, proper planning on the recycling issue should be included in future strategy development.

The legislation is the last issue being discussed in the survey. The main challenge involved is concern on the company's intellectual property such as patent and copyright. Besides, data sharing and collaboration with external parties will widely occur throughout construction life cycle to avoid silo work also contribute to the revolution 4.0 challenges. Thus, a proper law needs to be created to avoid any cybersecurity and data theft problem especially personal information.

5 DISCUSSION

Against these issues, there does exist the critical need for the strategic development to overcome any challenges raise from the new era of revolution. All six categories are important and related to each other as it represents the whole problem of Revolution 4.0 implementation. The development and adoption of new technologies into the construction industry is risky since it still new especially for developing countries. But, benchmarking the successfulness of developed countries such as Germany that highly implement Industrial Revolution 4.0 into their sector can be an initial step for any developing countries.

To extensively acquire the benefits of Revolution 4.0, political, economic, social, technological, environmental, and legal challenges have to be grasped. For instance, companies have to deal with unclear digital operations vision by re-structuring and rebuilding the company's approaches. Aside from that, high implementation costs together with unclear return of investment, lack of skilled staff, concern on environmental impact and data security and data protection problem should not be forgotten. Firms can hold back for a while on the decision of joining the fourth industrial revolution but the process of benchmarking benefits and challenges should be done since now. Seeing the benefits overweigh the challenges could bring out different perspectives. Slowly, digitalization and digitization can be applied in industry activities.

In spite of that, the adoption of the fourth industrial revolution concept can help the construction industry to transform to a technology-driven industry and catch up the other industries especially manufacturing that has been successfully implementing Industry 4.0. To accelerate its transition to the digital future construction industry, future work should involve the strategies and action plan. There are also few papers which manage the issues that emerge. In this sense, future paper should provide assistance by not only allowing business executives to practice benchmarking on challenges but also by giving business executives or researchers an idea of what strategies need to be conducted.

6 CONCLUDING REMARKS

In this paper, the main aim was to explore the challenges of revolution 4.0 relating technologies in the construction industry from different categories. Based on the survey among large constructions' firm, the following conclusions are drawn:

- The construction industry is a sector that needs to be focused in the future.

- The way towards the wider deployment of the Revolution 4.0 production concept is still long. There are only very few Revolution 4.0 enterprises, mostly new enterprises built to prove the concept and construction industry yet still far behind.
- There are variety of different issues facing construction in the context of Revolution 4.0.
- Lack of public policies, high cost for implementation, unreliable broadband connectivity, low awareness of Industry 4.0 and its applications among companies, increase the production of metal and concerns around loss of control over your company's intellectual property are the main challenges of the construction industry in the era of Revolution 4.0.

ACKNOWLEDGEMENTS

The authors would like to thank Universiti Teknologi Malaysia for supporting with financial grants, Cost Centre No: Q.J130000.2522.19H53, Q.J130000.3551.06G64, GreenPROMPT research team members and Department of Construction Management, UTM CRC, together with the opportunity to conduct the research.

REFERENCES

[1] Hidayatno, A., Destyanto, A.R. & Hulu, C.A., Industry 4.0 technology implementation impact to industrial sustainable energy in Indonesia: A model conceptualization. *Energy Procedia*, **156**, pp. 227–233, 2019.
[2] Schumacher, A., Nemeth, T. & Sihn, W., Roadmapping towards industrial digitalization based on an Industry 4.0 maturity model for manufacturing enterprises. *Procedia CIRP*, **79**, pp. 409–414, 2019.
[3] Osunsanmi, T.O., Aigbavboa, C. & Oke, A., *Construction 4.0: The Future of the Construction Industry in South Africa*.
[4] World Economic Forum, *Shaping the Future of Construction: A Breakthrough in Mindset and Technology*, World Economic Forum (WEF), 2016.
[5] Oesterreich, T.D. & Teuteberg, F., Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry*, **83**, pp. 121–139, 2016.
[6] Vaidya, S., Ambad, P. & Bhosle, S., Industry 4.0: A glimpse. *Procedia Manufacturing*, **20**, pp. 233–238, 2018.
[7] Rojko, A., Industry 4.0 concept: Background and overview. *International Journal of Interactive Mobile Technologies (iJIM)*, **11**(5), pp. 77–90, 2017.
[8] Sanchez, D.O.M., sustainable development challenges and risks of Industry 4.0: A literature review. *2019 Global IoT Summit (GIoTS)*, IEEE, pp. 1–6, 2019.
[9] Boyes, H., Hallaq, B., Cunningham, J. & Watson, T., The industrial internet of things (IIoT): An analysis framework. *Computers in Industry*, **101**, pp. 1–12, 2018.
[10] Fonseca, L.M., Industry 4.0 and the digital society: Concepts, dimensions and envisioned benefits. *Proceedings of the International Conference on Business Excellence*, **12**(1), pp. 386–397, 2018.
[11] De Lange, P., Bähre, B., Finetti-Imhof, C., Klamma, R., Koch, A. & Oppermann, L., Socio-technical challenges in the digital gap between building information modeling and Industry 4.0. *STPIS@ CAiSE*, pp. 33–46, 2017.
[12] Stasiak-Betlejewska, R. & Potkány, M., Construction costs analysis and its importance to the economy. *Procedia Economics and Finance*, **34**, pp. 35–42, 2015.

[13] Chen, Q., de Soto, B.G. & Adey, B.T., Construction automation: Research areas, industry concerns and suggestions for advancement. *Automation in Construction*, **94**, pp. 22–38, 2018.
[14] Liu, B., Construction robotics technologies 2030. Master's thesis, 2017. http://resolver.tudelft.nl/uuid:fcacf6fb-112c-453f-9903-8ec53274153f.
[15] Bonilla, S., Silva, H., Terra da Silva, M., Franco Gonçalves, R. & Sacomano, J., Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges. *Sustainability*, **10**(10), p. 3740, 2018.
[16] JBKnowledge, *The 6th Annual Construction Technology Report*, 2017.
[17] Anuar, K.F. & Abidin, M.H.I.Z., The challenges in implementing building information model (BIM) for SME's contractor in the construction industry. *Research Journal*, **40**, 2015.
[18] Autodesk, *Strategic Industry Foresight: The Digitalization of Infrastructure*, 2017.